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Another Look at Storage Requirements for Bank Drive-In Facilities

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ABSTRACT

Observations of the operation and performance of bank drive-in facilities in Lincoln, Nebraska, indicated that current storage requirements for these facilities were excessive. The objective of this research was to determine why these theoretically and empirically developed requirements were excessive and to develop more reasonable storage requirements. Arrival and service-time data collected at bank drive-in facilities were analyzed. It was determined that the arrivals were Poisson. But, contrary to the usually employed queuing theory assumptions of negative exponential serving times, which had been used to develop previous storage requirements, the service-time distributions were found to be gamma distributions with shape parameters between 2.75 and 5.00. Because of the intractability of using queuing theory with gamma service-time distributions, simulation models of single-queue and multiple-queue, multiple-channel queuing systems typical of bank drive-in facilities were developed and validated. The models were then used to determine more appropriate storage requirements.

Before April 1981 the storage requirements for bank drive-in facilities imposed by the city of Lincoln, Nebraska, were those given in Table 1. These requirements were developed from a review of the literature, primarily papers written by Woods and Messer (1) and Scifres (2), and the results of field studies conducted by the city in 1974, which in general confirmed the findings presented in the literature. These requirements were generally accepted as reasonable for several years. Beginning in 1980 they were challenged for requiring too much storage, and the need for updated studies became apparent.

TABLE 1 City of Lincoln, Nebraska, Drive-in Bank Storage Requirements Before April 1981

No. of Windows	Minimum Storage Required[a,b] (vehicles)
1	7
2	14
3	21
4	28
5	30
6	30

[a]In addition to the service position.
[b]22 ft per vehicle required in storage lanes.

The need for updated studies resulted primarily from major changes in the banking industry in Lincoln. Among these changes were

1. A sharp increase in the number of drive-in facilities available, spreading the business around and reducing peaking at any one facility.
2. The introduction of 24-hour electronic teller machines at sales points such as grocery stores provided a new convenience for customers. This raised the customers' expectations and reduced their tolerance of delay.
3. There was an increased trend toward staggered payrolls among major employers, which reduced peaking characteristics for deposits and withdrawals.

Consequently, in early 1981, the city conducted studies of traffic operations at drive-in banking facilities to determine the reasonableness of its storage requirements. A total of 1,142 transactions were observed during which the average traffic intensity was 0.89. However, the maximum queue length observed in any one storage lane was only five vehicles, and it existed for only 18 sec. Otherwise, the maximum queue length was four vehicles. The average transaction time observed was 2.12 min, which is considerably lower than the average service times often assumed in design guidelines (1,2). In addition, the average time a vehicle spent in the system (i.e., waiting time plus service time) was 3.55 min, which is also much less than the waiting time normally used in the development of design guidelines (1,2).

On the basis of the results of these studies, it was concluded that the current standards were unreasonable in that they did require too much storage. Therefore, revision of the storage requirements for bank drive-in facilities was recommended, and revised requirements were adopted by the Lincoln City Council in April 1981. The revised standards require storage for four vehicles per drive-in window and storage for 20 vehicles maximum for an entire facility.

OBJECTIVE

Although the storage requirements were revised out of practical necessity, questions remained about why these empirical standards were so different from the city's previous standards and the guidelines recommended in the literature (1,2). Therefore, the objective of the research reported in this paper was to determine the reasons for these discrepancies and develop storage requirement guidelines for bank drive-in facilities.

PROCEDURE

A bank drive-in facility is a queuing system. Depending on its configuration, it may be classified as a single-queue, multiple-channel system or a multiple-queue, multiple-channel system. In a single-queue, multiple-channel system all vehicles wait for service in one line. If the distribution of arrivals is Poisson and the distribution of service times is negative exponential, the operation and performance of this type of system can be evaluated using queuing theory as was done by Woods and Messer (1). Otherwise, evaluation using queuing theory may be intractable. In a multiple-queue, multiple-channel system vehicles wait in queues in front of each drive-in window. When the queue storage of all windows is full, vehicles wait in a single queue. Regardless of the nature of the arrival and service-time distributions, the evaluation of the operation and performance of this type of system using queuing theory is intractable.

Because of the limitations of queuing theory, simulation was used in this research. Simulation models were developed and validated for both types of bank drive-in window queuing systems. The data collected by the city in early 1981 were analyzed to determine the nature of the observed arrival and service-time distributions. The results of this analysis and the simulation models were then used to determine storage requirements of bank drive-in facilities.

ARRIVAL AND SERVICE-TIME DISTRIBUTIONS

The arrival and service-time data collected by the city during its studies of bank drive-in facilities in early 1981 were analyzed to determine the nature of their distributions. The chi-square goodness-of-fit test was applied at the 0.01 level of significance to determine the arrival and service-time distributions in each of the 12 peak hours studied. As as result of these tests, it was found that all 12 of the arrival distributions were Poisson, a finding consistent with the common assumptions of queuing theory and the observations of previous studies of drive-in banking facilities (1,3).

The results of the analysis of the service-time distributions were not consistent with the usual assumption of queuing theory that service times are distributed negative exponentially. If fact, none of the 12 service-time distributions was found to be negative exponential. Instead, all but one of them were found to fit a gamma distribution with a shape parameter between 2.75 and 5.00. This finding is consistent with that of Thurgood (4), who found that the service-time distributions of drive-in banking facilities in the Chicago area were definitely not negative exponential.

SIMULATION MODELS

Two simulation models of bank drive-in facilities were developed. One was a model of the single-queue, multiple-channel system, and the other was a model of the multiple-queue, multiple-channel system. Both of these models were written in the GPSS/H simulation language (5), a discrete simulation language commonly used to simulate queuing systems.

Using the validation procedure outlined by Law and Kelton (6), the outputs of the simulation models were first compared with the theoretical results of queuing theory. Fifty replications of 100 hr each were simulated for worst-case conditions (7). In all cases, the model output deviated from the theoretical results by less than 10 percent. Also, no significant differences were found at the 0.05 level of significance between the model and the theoretical mean values of number in the system, number in the queue, and time in the system.

STORAGE REQUIREMENTS

Previous Studies

A search of the literature published in the past 15 years, during the tremendous increase in the number of drive-in banking facilities, revealed little information on storage requirements for these facilities. One exception was a paper by Woods and Messer (1) published in 1970, which provided guidelines for the design of drive-in banking facilities. Based on field observations of 227 service times, they concluded that the "usually assumed" average service time of 1.5 min or 40 vehicles per hour per window was "reasonably valid" and that the service times tended to be "negative exponential in nature." Scifres (2) also developed guidelines for the planning and design of drive-in financial institutions.

Model Results

In general, the theoretically based guidelines developed by Woods and Messer require less storage than do the empirically based guidelines developed by Scifres. The traffic intensity used by Woods and Messer was 0.875 and the average traffic intensity observed by the city was 0.89. The expected average time in the system used by Woods and Messer was 5 min and the average time in the system observed by the city was 3.55 min. Because of this consistency, the simulation models were used to develop storage requirements for conditions similar to those used by Woods and Messer.

Therefore, a traffic intensity of 0.875 was used in conducting the simulation runs, and storage requirements were determined for 5 and 15 percent probabilities of the queue exceeding the storage provided. Also, Poisson arrivals were used in all cases. However, unlike Woods and Messer, gamma service-time distributions were used instead of the negative exponential service-time distribution. Storage requirements were determined using gamma service-time distribution with shape parameters of 2.75 and 5.00, which was the range of gamma service-time distributions observed by the city of Lincoln.

The storage requirements determined using the simulation models and the gamma service-time distributions are given in Tables 2 and 3. The storage requirements for single-queue, multiple-channel facilities are given in Tables 2, and those for multiple-queue, multiple-channel facilities are given in Table 3. Also given in these tables are the storage requirements determined by Woods and Messer using the negative exponential service-time distribution.

TABLE 2 Storage Requirements for Single-Queue, Multiple-Channel Bank Drive-in Facilities[a,b]

No. of Drive-in Windows	Minimum Storage (P = 15%)[c] (vehicles/window): Negative Exponential[d]	Gamma 2.75[e]	Gamma 5.00[f]	Desirable Design Storage (P = 5%)[c] (vehicles/window): Negative Exponential[d]	Gamma 2.75[e]	Gamma 5.00[f]
2	12	6	5	20	12	11
3	12	6	5	20	12	11
4	11	6	5	20	12	10
5	11	6	5	19	12	10
7	10	5	4	19	12	10
9	10	5	4	18	11	9

[a]In addition to the service positions.
[b]Traffic intensity = 0.875 and Poisson arrivals.
[c]P = percent of time that queue length would be greater than the storage provided.
[d]Negative exponential distribution of service times.
[e]Gamma distribution of service times with shape parameter = 2.75.
[f]Gamma distribution of service times with shape parameter = 5.00.

TABLE 3 Storage Requirements for Multiple-Queue, Multiple-Channel Bank Drive-in Facilities[a,b]

No. of Drive-in Windows	Minimum Storage (P = 15%)[c] (vehicles/window): Negative Exponential[d]	Gamma 2.75[e]	Gamma 5.00[f]	Desirable Design Storage (P = 5%)[c] (vehicles/window): Negative Exponential[d]	Gamma 2.75[e]	Gamma 5.00[f]
2	7	4	3	10	6	6
3	4	3	2	7	4	4
4	3	2	1	5	4	4
5	3	1		4	3	2
7	2			3	2	1
9	2			2		

[a]In addition to the service positions.
[b]Traffic intensity = 0.875 and Poisson arrivals.
[c]P = percent of time that queue length would be greater than the storage provided.
[d]Negative exponential distribution of service times.
[e]Gamma distribution of service times with shape parameter = 2.75.
[f]Gamma distribution of service times with shape parameter = 5.00.

Examination of these tables reveals that the storage requirements determined using the gamma service-time distributions are in all cases less, and in many cases substantially less, than those determined using the negative exponential service-time distribution. Of course, this is due to the fact that the gamma distributions have variances that are lower than those of the negative exponential distribution, and, as the shape parameter is increased, the variance is reduced. Consequently, the storage requirements determined using the gamma service-time distribution with a shape parameter of 5.00 are the lowest in every case.

Comparison of the data in Tables 2 and 3 indicates that in general less total storage is required in single-queue, multiple-channel systems than in multiple-queue, multiple-channel systems. This is to be expected because of the pooling of service provided in the single queue, multiple-channel system.

CONCLUSION

According to the findings of this research, the usual queuing theory assumptions of Poisson arrivals and negative exponential service times are not valid for the determination of storage requirements for bank drive-in facilities. Although the distribution of arrivals at bank drive-in facilities was found to be Poisson, the distribution of service times at these facilities was not found to be negative exponential. Instead, the distribution of service times was found to be a gamma distribution with a shape parameter ranging from 2.75 to 5.00. Consequently, storage requirements developed using queuing theory with the usual assumptions, as was done in previous studies (1,4), are excessive. Although such requirements may be considered conservative by a traffic engineer, they are considered extravagant by the financial institutions.

Therefore, it was concluded that the storage requirements given in Tables 2 and 3, which were determined in this research using simulation models and gamma service-time distributions, should be used as guidelines in the planning and design of bank drive-in facilities. It should be noted that these requirements were developed using a traffic intensity of 0.875. This was the same traffic intensity used by Woods and Messer (1), and it was found to be consistent with observations of peak-hour operations at bank drive-in facilities in Lincoln, Nebraska.

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